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REVISION OF SHARKS OF GENUS *ISURUS* WITH DESCRIPTION OF A NEW SPECIES (GALEOIDEA, LAMNIDAE)[1]

By J. A. F. Garrick[2]

The genus *Isurus* comprises the mako or mackerel sharks, worldwide in distribution throughout tropical and temperate seas. Opinion from recent accounts as to the number of extant species in the genus ranges from two or three (Bigelow and Schroeder, 1948) to four (Smith, 1957, 1958). In the study reported below, considerably more material has been examined than was available to other workers, and it is concluded that the 12 nominal species of *Isurus* represent only 1 worldwide species. However, in addition, there is another very distinctive species which does not appear to have been described.[3] Presentation of the evidence for these findings and description of the new species are the purposes of this paper.

This study is based on 35 specimens from which fairly complete measurements of external dimensions have been taken. For another 8 specimens only incomplete data are available. In addition some

[1] This study has been supported by grants from the University of New Zealand, by Atomic Energy Commission contract AT(30-1)2409, and by National Science Foundation Grant GB-245.

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[3] At the time this paper was in galley, Guitart Manday (July 1966) described, under the name *Isurus paucus*, a mako shark that is clearly the same as the species which I describe as new in this account. For further details, see Addendum.

proportions have been extracted from the original descriptions or from the illustrations of the types of the nominal species *I. africanus*, *I. bideni*, *I. cepedii*, *I. dekayi*, *I. glaucus*, *I. gomphodon*, *I. guentheri*, *I. huidobrii*, and *I. tigris*. Comparable data could not be obtained from the descriptions of *I. mako*, *I. oxyrinchus*, and *I. spallanzani* for a variety of reasons: either no measurements or proportions were given, or no indication of the size of the specimen concerned was included, or illustrations were poor or lacking. The reliability of the data from some of the original descriptions is discussed on page 666 and elsewhere in this paper.

Seventeen of the specimens for which there are full data have been examined and measured by me. These include: one from the western North Atlantic; one from the eastern North Atlantic; two from Japan; three from California; seven from New Zealand; one from South Africa; and two from the Indian or Pacific Oceans (exact locality uncertain). Measurements were made in the manner outlined by Bigelow and Schroeder (1948, p. 61).

Data from 13 specimens taken in the central Pacific during 1952 through 1955 by the program of Pacific Oceanic Fishery Investigations of the U.S. Fish and Wildlife Service were supplied by Dr. Donald W. Strasburg. These were reported earlier in summarized form by Strasburg (1958). J. Moreland provided measurements of a New Zealand specimen, and S. Gruber supplied measurements of one from New York.

Information was obtained from recently published accounts of four specimens from Madagascar (Fourmanoir, 1961), three specimens from South Africa (Smith, 1953, 1957, 1958), and two specimens from the western North Atlantic (Bigelow and Schroeder, 1948).

The material included 31 males, 11 females, and 6 specimens for which the sex was not recorded. No sexual dimorphism was observed in proportions. In total length the specimens ranged from late embryos 605 mm. long to an adult of 3,200 mm., the latter a cast of a New Zealand female in the Auckland Museum.

Many of the specimens were discarded after they had been measured, but some were preserved whole. The latter are listed under Study Material in the accounts of the two species given here.

My thanks are due to the many colleagues who have assisted in this study by providing specimens and data. To those at the institutions mentioned variously in this account I would add Dr. T. Abe (Tokaiku Suisan Kenkyujo, Tokyo, Japan) for his considerable contribution in supplying three specimens of the new species of *Isurus* described here; F. Begley of Awanui, New Zealand, for assistance in obtaining specimens of New Zealand makos; Dr. L. R. Richardson (formerly of Victoria University of Wellington, New Zealand) for his

sustained interest and discussions on the problem; and several colleagues who have read and offered valuable suggestions on the manuscript. The illustrations of the teeth of two makos (figs. 8, 9) are by Peter A. McCrery.

Although the nominal species treated here have been placed in several genera by some authors, opinion has stabilized in more recent years to include them all in *Isurus* Rafinesque. It will be apparent from the treatment of these nominal species in this account that recognition of *Isurus* alone is the only possible course.

The nominal species of *Isurus* listed in the order in which they were proposed[4] are:

species	*locality*	*total length(s) of type(s)*
Isurus oxyrinchus[5] Rafinesque, 1810a	Sicily	—
Isurus spallanzani Rafinesque, 1810b	Sicily	—
Squalus (*Lamna*) *cepedii* Lesson, 1830	Tropical Atlantic	1830 mm.
Oxyrhina gomphodon Müller and Henle, 1841	oceanic	ca. 1700 mm.
Oxyrhina glauca Müller and Henle, 1841	Japan	1020 mm., 750 mm., 660 mm.
Isuropsis dekayi Gill, 1862b	New York	3100 mm.
Carcharias tigris Atwood, 1869	Massachusetts	2690 mm.
Lamna guentheri Murray, 1884	Kurrachee, India	2580 mm.
Lamna huidobrii Philippi, 1887	Chile	2900 mm.
Isurus mako Whitley, 1929	New Zealand	—
Isurus bideni Phillipps, 1932	South Africa	1195 mm.
Isurus africanus Smith, 1957	South Africa	2540 mm.

The characters separating *Isurus* from the other two genera, *Lamna* and *Carcharodon*, in the family Lamnidae are: upper teeth smooth edged, lacking lateral basal denticles; first dorsal origin definitely behind a vertical through posterior (inner) corner of pectoral fin; and no secondary lateral keel along anterior part of caudal fin. In *Lamna* the teeth are smooth edged but have lateral basal denticles, at least in subadults and adults. In *Carcharodon* the teeth are serrated. Both *Lamna* and *Carcharodon* have the first dorsal origin anterior to a vertical through the posterior corner of the pectoral. *Lamna*, but

[4] See Addendum.

[5] Tortonese (1956, p. 106, ftn. 1) claims that, under Article 19 of "The Code of Zoological Nomenclature," this spelling should be emended to "*oxyrhynchus*." However, if we consider that Rafinesque used the spelling "*oxyrinchus*" twice in his 1810a account (once on page 12, and again on plate 13) and repeated it in his 1810b account (p. 45), and nowhere used the spelling "*oxyrhynchus*," we have no reason to believe that "*oxyrinchus*" was an inadvertent error. Consequently, according to Article 32(b), the spelling "*oxyrinchus*" must be treated as the correct original spelling and is not to be emended.

not *Carcharodon*, has a secondary lateral keel on the anterior part of the caudal fin.

Comparing the original (and some later) accounts of the nominal species of *Isurus* with the diagnostic criteria mentioned above reveals discrepancies in a few cases. For example, the original illustration of *I. gomphodon* in Müller and Henle (1841, pl. 28) shows the first dorsal origin above the pectoral axil—a character of *Lamna*. However, the teeth, as illustrated, are clearly those of an *Isurus*, and likewise there is no secondary caudal keel. Müller and Henle's illustrations are, for the most part, accurate representations, so one is led to the assumption that the illustration of *I. gomphodon* was made from a distorted specimen. The type and only specimen, a mounted skin, was deposited in the Berlin Museum but unfortunately cannot be found. Compared with other makos, the illustration of *I. gomphodon* shows a considerably shorter body sector as measured between pectoral axil and pelvic origin (see table 1, E). Also the first dorsal fin is higher than usual (fig. 3), and the pectoral is longer (figs. 1–2)—though not as long as that of the new species described below. On this evidence there is reason to believe that the skin of the type of *I. gomphodon* underwent shrinkage along its midsector when it was being mounted. Consequently, the proportions of *I. gomphodon* must be used with caution.

Isurus spallanzani, first illustrated in Bonaparte (1839, pl. 136, fig. 1) from an Italian specimen, is also shown with the first dorsal origin over the pectoral axil, but again it is clear that the specimen was an *Isurus*. Conversely, Bonaparte's illustration (1835, pl. 134, fig. 2) in the same account, of *Lamna cornubica*, has the first dorsal origin slightly behind the pectoral posterior corner—a character of *Isurus*. It must be presumed that Bonaparte's illustrations are inaccurate in these features for subsequent accounts of *Isurus* and *Lamna* from Italian waters (e.g., Tortonese, 1956) do not agree with Bonaparte but instead show the "normal" positioning of the first dorsal fin relative to the pectoral fin.

The above-mentioned discrepancies make understandable the confusion which has arisen between *Isurus* and *Lamna*. The persistence of such confusion is exemplified by Waite's (1921, p. 21, fig. 27) illustration of an Australasian specimen of *Lamna nasus* as *Isurus glaucus*. Waite's illustration was later redrawn by Barnard (1925, pl. 1, fig. 6) who used it for *I. glaucus* in his account of South African fishes. Whitley (1940, p. 123, fig. 130) also used Waite's illustration but identified the shark as *I. mako*.

Isurus guentheri stands noticeably apart from the other 11 nominal species in having many more teeth. Murray's (1884, pp. 348–351) account of the type, the only information available for the species,

credits it with having $\frac{22}{28}$ teeth in each side of the jaws. In all other makos so far reported there is a range of $\frac{10 \text{ to } 14}{10 \text{ to } 15}$ teeth in each side of the jaws. Murray's account stresses the fact that his species has many teeth, thereby lessening the likelihood that his count is in error. However, because no other mako has been reported with a comparable number of teeth, and in view of the fact that Murray's count is twice that for other makos, I believe that Murray's count should be regarded as in error. I, therefore, follow Smith (1957, p. 92) and some earlier workers in treating Murray's count of $\frac{22}{28}$ as being a total count rather than the count of the teeth in each side of the jaws.

Examination of my data on the proportional dimensions of the makos used in this study shows that only in pectoral fin length is there any clear-cut evidence of the existence of more than one species. In figure 1, where the length of the pectoral fin relative to prepectoral length is expressed against total length, five specimens stand well apart from the remainder in having considerably longer pectorals. These

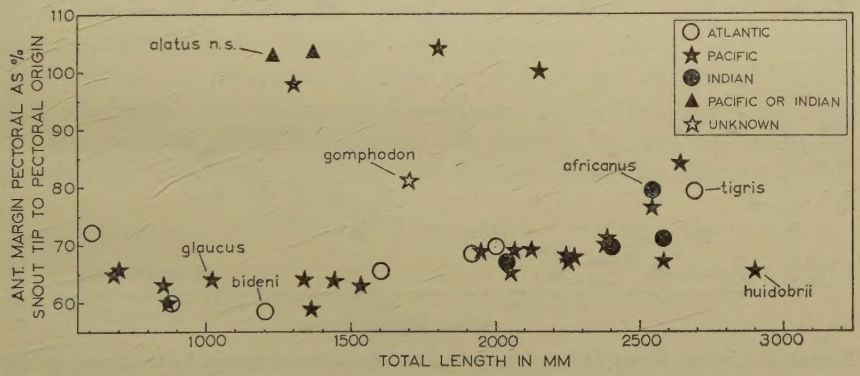

FIGURE 1.—*Isurus*, separable into long-finned and short-finned species by the length of the pectoral fin relative to prepectoral length (identified specimens are types of the nominal species).

specimens include three from the central Pacific (data from Dr. Donald W. Strasburg) and two specimens supplied by Dr. Tokiharu Abe. The latter two were taken by Japanese long-line vessels in either the Pacific or Indian Oceans. The only specimen that does not obviously fit within the two groupings in figure 1 is the type of *I. gomphodon* which is more or less intermediate though favoring the short-finned group. However, as already discussed, the dimensions of *I. gomphodon* are suspect, and its fins are probably relatively shorter than its illustrated total length suggests. On this basis *I. gomphodon* can be aligned with the short-finned group.

Figure 2, where pectoral fin length as a percentage of total length is expressed against total length, shows the same two groupings as in figure 1. The long-finned group includes the five specimens which were distinctive in figure 1 and also two more which were omitted in figure 1 for lack of definite data on head length. These two are a specimen from off Madagascar, reported in Fourmanoir (1961, pp. 78–79), and the type of *I. cepedii*. Fourmanoir's records indicate that he had short-finned makos as well as the long-finned specimen, and he notes that there were differences in form and weight "sans pouvoir définir avec certitude une deuxième espèce." One apparent error in the dimensions which Fourmanoir gives for his long-finned specimen (2,180 mm. total length) is the length from snout tip to pectoral origin (800 mm.). This is 36.7 percent of the total length, a percentage far too great for any mako. Presumably the 800 mm. length was meant to be for snout tip to first dorsal origin, as this dimension is omitted for the long-finned specimen but supplied for the others.

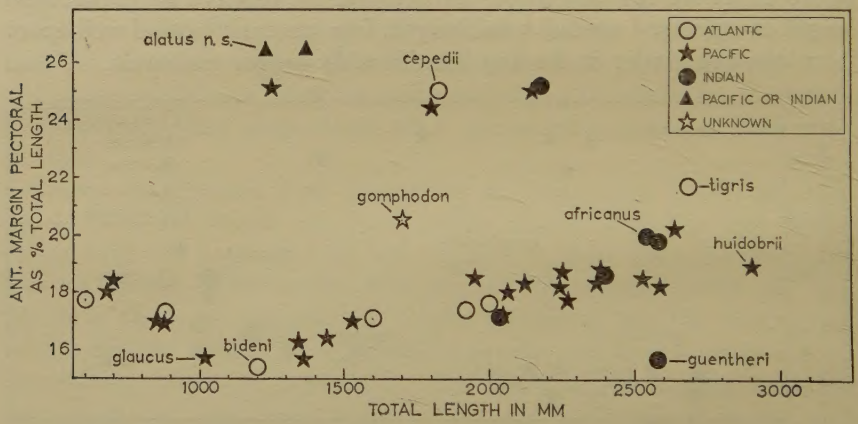

FIGURE 2.—*Isurus*, separable into long-finned and short-finned species by the length of the pectoral fin relative to total length (identified specimens are types of the nominal species).

If the type of *I. cepedii* rightly belongs with the long-finned group as figure 2 would indicate, then the long-finned species must take the name *I. cepedii*. However, for the reasons given below, I do not follow this course but instead describe the long-finned species as new (p. 677).

Isurus cepedii was described by Lesson (1830, p. 93) from a specimen 6 feet long taken in the tropical Atlantic. No illustration was given, but the description, particularly of the teeth and snout, is clearly that of an *Isurus*. The pectoral length is given as "près d'un pied et demi"; attention is drawn to the fact that this is an approximate length. The color on the underside of the snout is described as "Un blanc nacré," whereas in the three long-finned

makos which I have seen, the underside of the snout and around the lips is at least partly dusky. Lesson states that the caudal fin is deeply forked, the dorsal lobe with a "haut de 15 pouces," the ventral lobe with a "haut à peine de 8 Pouces." I assume that by "haut" Lesson meant the length of each lobe from its origin to tip. If this is so, Lesson's stated length of 15 inches for the dorsal lobe on a 6-foot long specimen is in agreement with other makos. But his stated length of 8 inches for the ventral lobe would be far too short. In all my material the length of dorsal lobe divided by the length of the ventral lobe ranges from 1.19 to 1.54, whereas in *I. cepedii* it is 1.88. The difference is sufficient to throw considerable doubt on the validity of Lesson's measurements, and in consequence of this, plus the discrepancy in snout color and the lack of type material to provide confirmation, I cannot regard the evidence as warranting the recognition of *I. cepedii* as a long-finned mako.

Figures 3, 4, 5, and table 1 were constructed from data on short-finned makos only. In figures 3–5 individual specimens are plotted, while in table 1 the data is summarized for three size groups, plus the types wherever possible. The various proportions represented in the figures and table are those which have been used by recent authors, particularly Bigelow and Schroeder (1948), and Smith (1957, 1958), as diagnostic criteria for the several species of *Isurus* they recognize. In summary, these diagnostic criteria are based on: the proportions of the first dorsal fin (height relative to base), its position and its shape; the height of the first dorsal fin relative to the

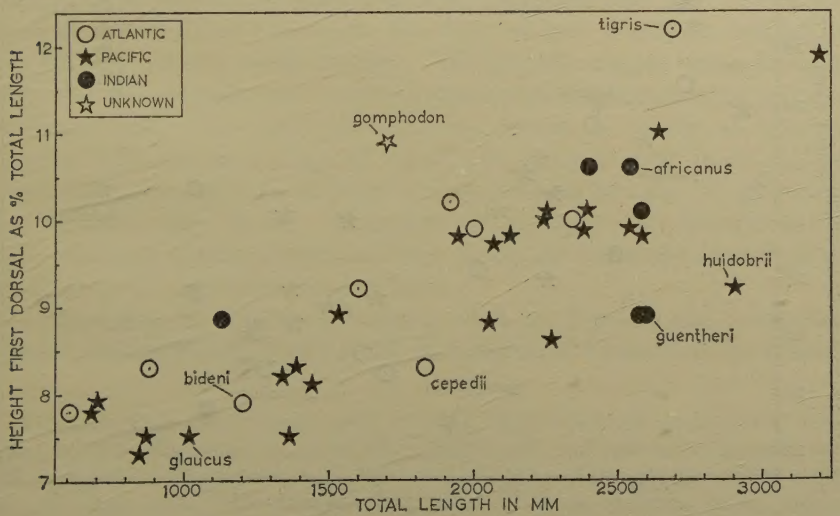

FIGURE 3.—*Isurus*, short-finned only, showing growth change in height of first dorsal fin relative to total length (identified specimens are types of nominal species).

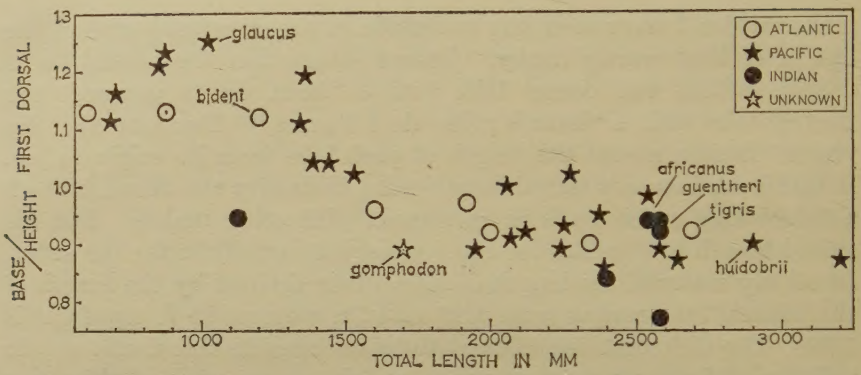

FIGURE 4.—*Isurus*, short-finned only, showing change with growth of the relative proportions of the first dorsal fin (identified specimens are types of nominal species).

head length; the head length relative to the distance between the pectoral fin axil and the pelvic fin origin; and the distance between the origins of the pectoral fin and first dorsal fin relative to parts of the head length. Figures 3–5 and table 1 do not support Bigelow and Schroeder's criteria for distinguishing Atlantic and Pacific species of *Isurus*, nor Smith's recognition of two or more species within each of the major oceans. Instead the figures and table provide fairly strong evidence that short-finned makos undergo considerable change with growth in some proportions and are variable in others. The amount of variation is large, but much of it may be due to differences

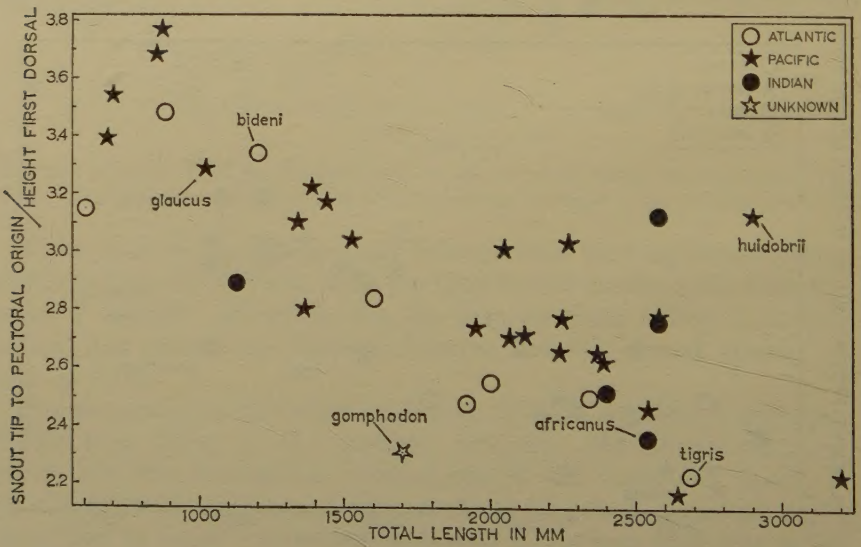

FIGURE 5.—*Isurus*, short-finned only, showing growth change in the height of the first dorsal fin relative to prepectoral length (identified specimens are types of nominal species).

in methods of measurement rather than to real differences. To what extent this is true cannot be assessed, for only a few of the many accounts which were abstracted to provide data used in the figures and table give any indication of the measuring methods used. Examples of the growth change and variation shown in the figures and table are as follows. The height of the first dorsal fin undergoes a very significant proportional increase with growth (fig. 3) while its base remains a constant proportion (table 1, A). The ensuing relationship of first dorsal height to base[6] with growth is as in figure 4. Prepectoral length shows no obvious change with growth but is rather variable (table 1, B). Comparing prepectoral length with first dorsal height relative to total length gives the plot shown in figure 5. The distance between the pectoral axil and the pelvic fin origin increases proportionately with growth (table 1, E). The distance between the pectoral fin origin and the first dorsal fin origin does not show growth change but is variable at all sizes (table 1, D); the relationship of this distance to the length from the posterior of the eye to the first gill opening is summarized in table 1, H. Various other proportions which have been used by Bigelow and Schroeder (1948) and Smith (1957) are given in table 1, C, F, G, I, and J; these similarly show growth change and variation but need not be discussed further here.

One other character which has been thought to be of prime diagnostic significance is the shape of the first dorsal fin apex. A broadly rounded apex has been regarded as a character of *I. glaucus*, while a more angular or acutely angled apex has been ascribed to *I. oxyrinchus* and *I. tigris*. This character, like that of first dorsal fin height, is profoundly altered with growth. All juvenile makos have broadly rounded first dorsals, and in all the apex becomes increasingly angular with growth. The same phenomenon occurs in nearly all sharks. Figure 6 illustrates a range of fin shapes, with growth, in four New Zealand makos, plus an Atlantic embryo which has the "*I. glaucus*," i.e., Pacific, type of fin. According to contemporary accounts, the New Zealand makos illustrated here would be variously identified as *I. glaucus*, *I. oxyrinchus*, and *I. tigris*.

Comparing the diagnostic criteria used by Bigelow and Schroeder (1948) and by Smith (1957, 1958) with my data shows that the species

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[6] Krumholz' report (Copeia, 1957, no. 4, p. 302) of a large mako, 3,023 mm. long, from the Bahamas, gives its first dorsal height and base as 8.2 percent and 10.1 percent of total length respectively—dimensions that are quite unlike those of any large mako I have seen. Kodachromes of the Bahama mako, kindly loaned by Dr. Krumholz, clearly show that the quoted dorsal fin dimensions are in error—perhaps transposed—because the first dorsal height is noticeably greater than the base, rather than the reverse as stated in Krumholz' account.

recognized by these authors are largely dependent on specimen size. Thus only juveniles clearly fit the criteria of *I. glaucus*, while middle-sized specimens show more affinity with *I. oxyrinchus*, and large specimens usually agree with *I. tigris*. In the case of *I. glaucus* and *I. tigris* these size characterizations follow from the sizes of the types; the types of *I. glaucus* were juveniles, the largest being 1,020 mm. long (selected by Boeseman (1947, p. 217) as lectotype), and the type of *I. tigris* was a large adult, 2,690 mm. long. *Isurus oxyrinchus* has been interpreted in recent years mostly from the excellent account and illustrations of a specimen 1,640 mm. long in Bigelow and Schroeder (1948, p. 125, fig. 18). Application of Bigelow and Schroeder's and of Smith's criteria for the species does not produce clear-cut results when a series of specimens is examined. This of course would be expected in view of the evidence given here on the size-dependency of the criteria and on the variation which occurs. Thus Cadenat (1962, p. 309) reports that four West African specimens which he has examined show more affinity with *I. tigris* as recognized by Smith, but in some characters, differing from specimen to specimen, there is agreement with *I. oxyrinchus*. I have found similar overlap in New Zealand specimens which, if small, could be variously identified as *I. glaucus* or *I. oxyrinchus* depending on the character used, or if large could be *I. oxyrinchus* or *I. tigris*. Dr. F. Talbot informs me (personal communication) that a series of makos caught off Capetown offered the same problems.

Examination of the features which were thought distinctive for the nominal species of makos when first described does not provide any other evidence for recognizing more than one species of short-finned mako. Rafinesque (1810b, p. 60) distinguished his Mediterranean *I. spallanzani* from the Mediterranean *I. oxyrinchus* on the grounds that *I. spallanzani* lacked a lateral line. However, all makos have lateral lines. Lesson (1830, p. 93) did not diagnose his Atlantic *I. cepedii* and made no comparison with other makos. Müller and Henle (1841, p. 69) differentiated the Pacific *I. glaucus* from *I. gomphodon* (locality unknown) on the position and shape of the first dorsal fin—features already treated here. Gill (1862b, p. 409) named the Atlantic *I. dekayi* on De Kay's (1842, p. 352) account of *Lamna punctata*, but in neither account is there any discussion of the diagnostic characters. Atwood (1869, p. 268) compared his Atlantic *I. tigris* only with *Carcharias atwoodi* Storer which is now known to be a synonym of *Carcharodon carcharias*. Murray (1884, p. 349) differentiated his Indian Ocean *I. guentheri* from *I. glauca* and *I. spallanzani* (and from *Lamna cornubica*) on the basis of its greater number of teeth, the position and shape of the fins, the length of the caudal keel, and the presence of a prominent lateral line. The question of

the number of teeth has been discussed on page 666; I do not find any of the other so-called differences to be valid. Philippi (1887, p. 548) distinguished his eastern Pacific *I. huidobrii* from *Lamna cornubica* by its teeth. He implied the need for comparison with *I. spallanzani*, but otherwise there is no discussion of diagnostic features. Whitley (1929, p. 101) named the New Zealand *I. mako* on the characters given in Phillipps' (1926, p. 530) account of *I. glaucus*. Phillipps compared his material with *I. glaucus* of Müller and Henle and with that of Waite (1921, p. 21) which was, in fact, a specimen of *Lamna nasus*. The only character which Phillipps thought distinctive was the relative lengths of the dorsal and ventral lobes of the caudal fin. His figure for these, 1.27, comes well within the values given here (table 1, J) for other short-finned makos. Phillipps (1932, p. 227) named the South African *I. bideni* using the description in Whitley (1931, p. 140). He distinguished *I. bideni* from *I. mako* and *I. glaucus* on the height of the first dorsal fin, the shape and dimensions of the caudal fin, and the position of the anal fin, viz, "Anal base wholly behind second dorsal." Of these three, only the last-mentioned character is unusual. I have found no mako with the anal fin as far back, relative to the second dorsal fin, as Phillipps shows in his figure of *I. bideni*, and presume that the figure is inaccurate in this feature. Smith (1957, p. 96) provisionally proposed the subspecies *I. tigris africanus* for a 2,540 mm. specimen from South Africa on the grounds that its first dorsal fin was less acute apically and slightly lower than Atlantic and Australasian specimens of *I. tigris*. In a later account Smith (1958, p. 134) recognized his subspecies as *I. africanus* but without further clarification of its distinctive features. As can be seen from figure 3 in the present account, *I. africanus* does not merit specific status in regard to its first dorsal fin height.

Cadenat (1962, p. 305) has suggested the probability that a further and as yet unnamed species of *Isurus* is present in the tropical Atlantic. This *Isurus*, which Cadenat knew only from the head of a specimen taken by a Japanese long-liner south of Cape Verdes Islands, differs from other makos in the number and arrangement of the upper teeth. Its dental formula is $\frac{8\text{–}2\text{–}2\text{–}8}{12\text{–}12}$. In the upper jaw there are two large teeth close together on each side of the symphysis, followed by a distinct space separating them from the smaller lateral teeth. In all other makos, including the new species described on p. 677, there are similarly two large teeth on each side of the symphysis, but these are closely followed by a noticeably smaller tooth which in turn is separated by a space from the larger lateral teeth. Also most makos have more lateral teeth than Cadenat's specimen. The first upper tooth of Cadenat's specimen has an incomplete cutting edge along the lateral

margin of its cusp—it agrees therefore with short-finned makos in this respect and not with the long-finned species described as new here. Cadenat regarded as improbable the likelihood that his mako is abnormal, on the grounds that the abnormality would not be bilaterally symmetrical. Evaluation of the status of the specimen must await further material.

Cadenat also pointed out that of the *Isurus* material that he has examined, the jaws of 12 specimens from Madeira, Senegal, and the Ivory Coast in the collection of l'Institut Français d'Afrique Noire at Gorée, Senegal, are very consistent in having a dental formula of $\frac{10\text{–}3\text{–}3\text{–}10}{13\text{–}13}$. Jaws which Cadenat has seen from other localities show more or less variation, and Pacific specimens generally tend to have fewer lower teeth. The tabulation below gives frequency distributions for the number of lower teeth in *Isurus* specimens from the Pacific, Atlantic-Mediterranean, and Indian Oceans, using Cadenat's data plus my own. This tabulation tends to confirm Cadenat's view that Pacific specimens have fewer lower teeth, though a more adequate sample of Pacific material is needed to substantiate the view.

Counts of teeth in one-half of the lower jaw of *Isurus oxyrinchus* are as follows:

number of teeth	*Pacific*	*Atlantic-Mediterranean*	*Indian Ocean*	*total*
10			1	1
11	2	2		4
12	7	9		16
13	5	27	4	36
14		5		5
15	1	1		2
16	1			1

On the basis of the above discussion, I regard as conspecific all short-finned makos presently reported, viz, the 12 nominal species listed on page 665; they take the name *Isurus oxyrinchus* Rafinesque, 1810.

Isurus Rafinesque, 1810

Isurus Rafinesque, 1810a, p. 11. [Type species *Isurus oxyrinchus* Rafinesque, 1810a, by monotypy.]

For generic synonymy, see Bigelow and Schroeder (1948, p. 123).

Isurus oxyrinchus Rafinesque, 1810

Short-finned Mako

Isurus oxyrinchus Rafinesque, 1810a, p. 12, pl. 13. [Sicily.]
Isurus spallanzani Rafinesque, 1810b, p. 45. [Sicily.]
Squalus (*Lamna*) *cepedii* Lesson, 1830, p. 93. [Tropical Atlantic.]
Oxyrhina gomphodon Müller and Henle, 1841, p. 68, pl. 28. [Oceanic.]

Oxyrhina glauca Müller and Henle, 1841, p. 69, pl. 29. [Japan.]
Isuropsis dekayi Gill, 1862b, p. 409. [New York.]
Carcharias tigris Atwood, 1869, p. 268. [Massachusetts.]
Lamna guentheri Murray, 1884, p. 348. [Kurrachee, India.]
Lamna huidobrii Philippi, 1887, p. 548, pl. 3. [Chile.]
Isurus mako Whitley, 1929, p. 101. [New Zealand.]
Isurus bideni Phillipps, 1932, p. 227, fig. 2. [South Africa.]
Isurus africanus Smith, 1957, p. 96. [South Africa.]

STUDY MATERIAL.—Preserved: Mus. Comp. Zool. (Harvard) no. 37994, male embryo, 605 mm., Bahamas, Cat Cay, 1952, J. M. Olin; Univ. Zool. Mus. (Copenhagen) no. PO557, female embryo, 605 mm., Japan, Nagasaki, 1911, D. S. Jordan; Mus. Comp. Zool. (Harvard) no. 1039, male, 682 mm., Japan, Jan. 17, 1903, A. Owston; Univ. Michigan Mus. Zool. no. 94726, male, 705 mm., California, San Pedro market, 1931, L. A. Walford; Scripps Inst. Oceanogr. no. 62–386, male, 745 mm., Mexico, Baja California, between Guadalupe Island and mainland, June 1962, S. Kato; Scripps Inst. Oceanogr. no. 50-240, male, about 775 mm., California, San Diego, about 14 mi. W. of Point La Jolla, Nov. 17, 1950, B. Evernham; Univ. Michigan Mus. Zool. no. 177116, female, 842 mm., Japan, Suruga Bay, near Shimizu, July 1, 1929, C. L. Hubbs et al; Mus. Comp. Zool. (Harvard) no. 35071, male, 847 mm., Japan, Tokyo market, January 1939; Dominion Mus. (New Zealand) no. 2945, female, 871 mm., New Zealand, Bay of Islands, March 1960, J. Moreland; Scripps Inst. Oceanogr. no. 59–372, male, 1,340 mm., California, La Jolla, Nov. 5, 1959; Univ. California, Los Angeles no. 60–202, female, 1,365 mm., California, Palos Verdes, June 17, 1960; Dominion Mus. (New Zealand) no. 2178, male, 1,390 mm., New Zealand, Bay of Islands, March 1957; Dominion Mus. (New Zealand) no. 3014, female, 1,438 mm., New Zealand, North Cape, Feb. 28, 1955, P. Sheehan; U.S. Nat. Mus. no. 197706, female, 2,000 mm., eastern North Atlantic, west of the Azores, May 5, 1963, B. B. Collette; Dominion Mus. (New Zealand) no. 1279, male, 2,240 mm., New Zealand, Paraparaumu, Apr. 22, 1958, A. S. Henderson.

Type material of two of the nominal species recognized here as synonyms of *I. oxyrinchus* was examined. This material included the jaws of the 2,540 mm. male holotype of *I. africanus* at Rhodes University (Grahamstown, South Africa) and the lectotype and two paratypes of *I. glaucus* at the Rijksmuseum van Natuurlijke Historie (Leiden). The types of *I. glaucus* are mounted skins, from Japan (not Java as stated by Müller and Henle, 1841), collected by D. W. Burger, and are as follows: no. 2529, lectotype, male, about 1,020 mm.; nos. 2533 and 2587, paratypes, males, about 750 mm. and 660 mm., respectively.

Jaws of additional specimens were examined from the collections of the above-mentioned institutions and from others including the South African Museum (Capetown), the Institut Français d'Afrique Noire (Gorée, Senegal), the American Museum of Natural History (New York), and the California Academy of Sciences (San Francisco).

Discarded after measurement and examination: Two males, 1,050 mm. and 2,535 mm., and one female, 2,642 mm. from New Zealand; one female, 1,920 mm., from off Cape Peninsula, South Africa.

DIAGNOSIS.—An *Isurus* with short to moderately long pectoral fins, always shorter than length of head (pectoral fin length usually less than 70 percent of head length but up to 84 percent in very large specimens); with underside of snout and around mouth white in color; and with first tooth on each side of symphysis in both jaws having an incomplete cutting edge on its lateral margin (cutting edge extending only part way from tip of cusp toward base) except in very large specimens, 2,500 mm. long or more, where the cutting edge approaches or reaches the base.

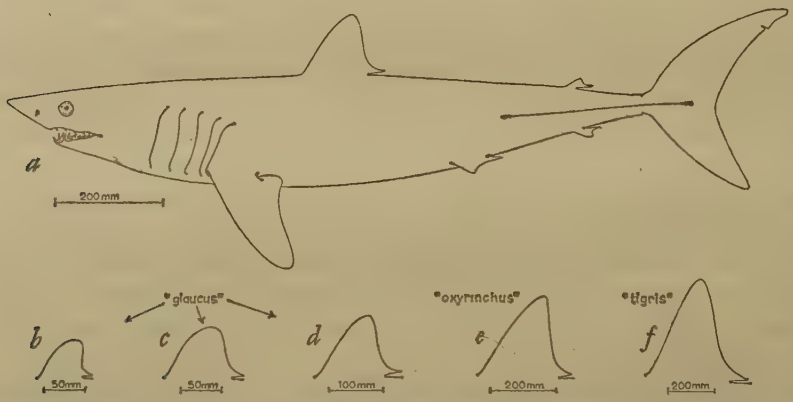

FIGURE 6.—*Isurus oxyrinchus: a*, Dom. Mus. (New Zealand) 3014, female, 1438 mm., New Zealand. First dorsal fins showing change in shape and proportions with growth: *b*, Mus. Comp. Zool. (Harvard) 37994, embryo, male, 605 mm., Bahamas; *c*, Dom. Mus. (New Zealand) 2945, female, 871 mm., New Zealand; *d*, specimen in fig. *a* above; *e*, male, 2535 mm, New Zealand; *f*, female, 3,200 mm., New Zealand (drawn from cast in Auckland Museum). (Names in quotation marks are nominal species to which the specimens previously would have been referred according to their fin shapes and proportions.)

DESCRIPTION.—For extensive descriptions of this species see Bigelow and Schroeder (1948, p. 124) and Smith (1953, p. 977; 1957, p. 94; 1958, p. 134), variously under the names *I. oxyrinchus*, *I. glaucus*, and *I. tigris*.

Table 2 gives the proportional dimensions of five specimens of *I. oxyrinchus* for comparison with those of the long-finned species. Vertebral counts and data for specimens of *I. oxyrinchus* do not show

any significant difference from those of the long-finned species but are given below for comparison:

Isurus oxyrinchus		number of vertebrae		
specimen	*locality*	*precaudal*[7]	*caudal*	*total*
Mus. Comp. Zool. (Harvard) 37994	Bahamas	110	80	190
Univ. Michigan Mus. Zool. 177116	Japan	108	79	187
Scripps Inst. Oceanogr. 50–240	California	112	80	192
Data from J. G. Casey on three specimens	New York-New Jersey	109–110	80–81	190–191
U.S. Nat. Mus. 197686	South Africa	111	79	190

Centra very regular along entire vertebral column. Centrum diameter much greater than centrum length even in longest monospondylous centra at posterior region of abdomen. Diplospondyly occurs over anterior third to middle of pelvic base.

$\frac{\text{Length}}{\text{Diameter}}$ of penultimate monospondylous centrum=0.46 to 0.55.

$\frac{\text{Length of penultimate monospondylous centrum}}{\text{Length of first diplospondylous centrum}}$=1.14 to 1.24.

Isurus alatus, new species[8]

Long-finned Mako

Isurus glaucus.—Strasburg (in part), 1958, p. 357. [Central Pacific.]
Isurus oxyrhynchus.—Fourmanoir (in part), 1961, p. 79. [Madagascar.]

Study Material.—Holotype: U.S. Nat. Mus. no. 197427, male, 1,233 mm., from the tropical Indian or Pacific Oceans, collected during 1962 by a Japanese long-liner, and supplied by T. Abe.

Paratypes: U.S. Nat. Mus. no. 197429, female, 1,372 mm., same data as holotype; U.S. Nat. Mus. no. 197435, mature male, incomplete, lacking caudal fin and first dorsal fin, 1,720 mm. long from snout tip to just in front of precaudal pits, same data as holotype.

Supplementary Material.—U.S. Nat. Mus. no. 196024, jaws, skin sample, photographs and measurements of male, 1,251 mm., from equatorial Pacific between 150° W. and 170° W., May 3, 1953, USFWS, Pacific Oceanic Fishery Investigations (MV *John R. Manning*, Cruise 15, Station 2); U.S. Nat. Mus. no. 196039, jaws, photographs, and measurements of male, 1,801 mm., from equatorial

[7] Precaudal centra include all complete centra anterior to a vertical through the forward margin of the upper precaudal pit.

[8] As mentioned in footnote 3, Guitart Manday (1966) has recently described this species under the name *I. paucus*, which, therefore, has priority.

Pacific between 150° W. and 160° W., Aug. 26, 1953, USFWS, Pacific Oceanic Fishery Investigations (MV *John R. Manning*, Cruise 16, Station 29); also measurements of male, 2,150 mm., from Pacific, north of Hawaiian Islands, between 22° N. and 47° N., and 159° W. and 177° W., Sept. 19, 1954, USFWS, Pacific Oceanic Fishery Investigations (MV *John R. Manning*, Cruise 22, Station 7).

DIAGNOSIS.—An *Isurus* with very long pectoral fins equal in length to head; with at least some dusky coloration on underside of snout and around mouth; and with first tooth on each side of symphysis in both jaws having a complete cutting edge (from tip of cusp to base) on its lateral as well as on its medial margin.

COMPARISON.—The very long pectoral fins of *I. alatus* readily distinguish this species from *I. oxyrinchus*. As can be seen in figure 1, the pectoral fins of *I. alatus* are equal to the head length, whereas in *I. oxyrinchus* they are not more than about 70 percent of the head length over most of the size range of specimens examined. Only in specimens of *I. oxyrinchus* of 2,400 mm. long or longer do the pectorals exceed 70 percent of the head length, and the highest value I have is 84 percent in a New Zealand specimen 2,642 mm. long.

Comparison of pectoral length as a percentage of total length relative to total length (fig.2) again indicates a clear-cut separation of *I. alatus* and *I. oxyrinchus*. However, the relative increase in pectoral length with growth in specimens of *I. oxyrinchus* of 1,200 mm. long and longer does mean that the largest adults of *I. oxyrinchus* approximate, but do not overlap, *I. alatus*. Information is desirable on larger specimens of *I. alatus* to indicate whether it shows a comparable relative increase in its pectoral length with growth. The apparent relative decrease in pectoral fin length which my data (fig. 2) show for specimens of *I. oxyrinchus* from birth size to about 1,000 mm. is, if valid, another interesting example of the variation in growth-change patterns in sharks.

As well as its longer pectoral fins, *I. alatus* has longer pelvic fins than *I. oxyrinchus* (figs. 6, 7; table 2). In *I. alatus* the anterior margin of the pelvic fin is equal to or only slightly shorter than the distal margin, whereas in *I. oxyrinchus* the anterior margin is noticeably shorter.

The dusky coloration on the underside of the snout of *I. alatus* contrasts strongly with the immaculate whiteness of this region in *I. oxyrinchus*. The duskiness increases with growth—hence the smallest specimens of *I. alatus* only have duskiness fringing the underside of the snout tip and around the mouth. In the largest specimen the duskiness is not only more extensive under the snout but is darker.

Several differences can be noted between the teeth of *I. alatus* and *I. oxyrinchus*. Those of *I. alatus* have noticeably broader cusps, are less flexuous, and less oblique (pls. 1, 2; figs. 8, 9). The first upper and lower teeth of *I. alatus* have on their lateral margins a cutting edge

which extends from the tip of the cusp to the base. The medial margins are similarly armed. The first tooth is therefore similar to the second tooth. In *I. oxyrinchus* (excepting largest adults) the first tooth in each jaw does not have a complete cutting edge on its lateral margin. It is therefore dissimilar from the second tooth, particularly in the upper jaw. The cutting edge on the lateral margin of the first tooth is present at the tip of the cusp but extends only part way to the base. The relative length of this cutting edge varies with growth. In juveniles the cutting edge may be only one-third or less of the length of the cusp, but in subadults and larger specimens it will commonly extend along two-thirds of the cusp. In large adults of 2,500 mm. or more the cutting edge approaches or reaches the base—when the distinction between *I. alatus* and *I. oxyrinchus* on this character disappears. The same can be said of tooth shape in large adults of *I. oxyrinchus* where the teeth are less flexuous and proportionately broader than those of smaller specimens—thus the teeth of large adults of *I. oxyrinchus* are like those of *I. alatus*.

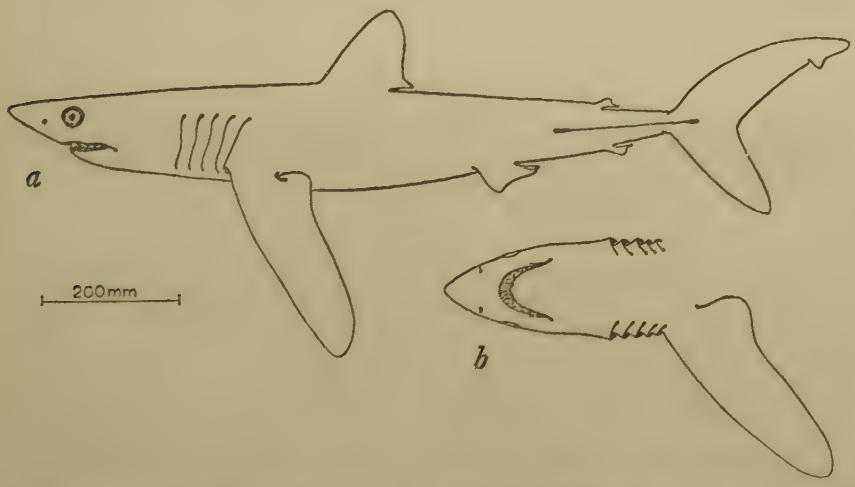

FIGURE 7.—*Isurus alatus*, new species: *a*, *b*, holotype, USNM 197427, male, 1233 mm., tropical Pacific or Indian Oceans.

Another difference between the teeth of the two species is in the position and shape of the third upper tooth. In *I. alatus* the third upper tooth is below the lateral margin of the palatine process of the palatopterygoquadrate cartilage and is only slightly oblique in shape (pl. 1). In *I. oxyrinchus* the third upper tooth is more medial in position, usually below the upper two-thirds of the lateral margin of the palatine process, and the tooth itself is more asymmetrical and oblique in shape.

The difference between the species in the shape of the tail, especially in the relative prominence of the terminal lobe of the dorsal lobe and the subterminal notch (figs. 6, 7), may not be so evident in large specimens. Usually the terminal lobe becomes smaller and less conspicuous with growth. If this is so in *I. alatus*, then adults of *I. alatus* should show a condition more like that of *I. oxyrinchus*.

The relative slenderness of *I. alatus* is difficult to evaluate because my material is in poor condition. However, my interpretation of *I. alatus* as a slender species compared with I. *oxyrinchus* is supported by Fourmanoir's data (1961, pp. 17, 79) which give the weight of a 2,180 mm. specimen, apparently *I. alatus*, as 70 kilograms, whereas two specimens of *I. oxyrinchus* of 2,580 mm. weighed 150 and 200 kilograms. Bigelow and Schroeder (1948, p. 128) give the weight of an 1,830 mm. *C. oxyrinchus* as 61 kilograms, and a 2,340 mm. specimen as 104 kilograms.

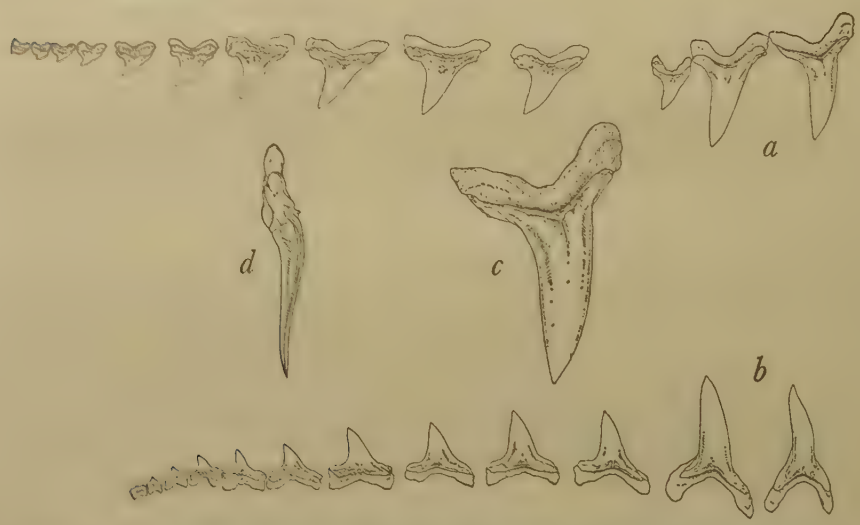

FIGURE 8.—*Isurus alatus*, new species, USNM 196039, male, 1801 mm., central Pacific: *a*, *b*, upper and lower teeth, right side; *c*, *d*, first upper tooth, right side, anterior and lateral views, showing complete cutting edge on lateral margin.

One further difference between the two species is in the size of the eye, that of *I. alatus* being slightly larger at all sizes than that of *I. oxyrinchus*.

Judging by the photographs of two central Pacific specimens (pls. 3,4), the first dorsal fin of *I. alatus* changes in shape and proportions with growth in a manner comparable to that of *I. oxyrinchus*.

DESCRIPTION.—Based mostly on the 1,233 mm. holotype and the 1,372 mm. paratype.

For proportional dimensions in percent of total length, see table 2.

Trunk slender, its height at pectoral origin about one-seventh of its length to subcaudal origin. Caudal peduncle notably flattened dorsoventrally, and expanded laterally to form a sharp-edged horizontal keel along midlevel of each side; anteriorly the keels become inconspicuous a little behind tips of pelvic fins, while posteriorly they extend onto anterior part of caudal fin. Lateral line not prominent. Upper and lower precaudal pits strongly developed, their anterior margins transverse and sharply defined.

Dermal denticles small, close packed, overlapping, circular in outline, each with three longitudinal ridges and three posterior marginal teeth, the latter relatively larger in denticles of smaller specimens, median tooth always longer than lateral teeth.

Head long, its length to fifth gill opening one-quarter of total length, its greatest width 2.2 to 2.1 in its length. Snout sharply pointed, conical, slightly depressed dorsally, its length to eye 4.2 to 4.3 in head. Prenarial length equal to internarial distance and 1.4 to 1.5 in preoral length. Eye large, circular, its diameter 2.8 to 3.1 in snout, its anterior margin slightly behind front of mouth. Nostrils almost transverse, small, their anterior margins with a low pointed lobe. Mouth large, rather long, upper lip broadly arched at front, lower lip not meeting upper even when mouth is closed; width of mouth 1.2 in its length. Labial furrows long, upper more than one-third length of mouth, lower about two-thirds as long as upper. Gill openings very large, their vertical lengths extending almost two-thirds of depth of body at same region; lower end of fifth gill opening extends beneath and slightly behind pectoral fin origin.

Teeth $\frac{12 \text{ or } 13\text{–}12 \text{ or } 13}{11 \text{ or } 12\text{–}11 \text{ or } 12}$, similar in upper and lower jaws, unicusped, narrowly triangular, smooth edged, with complete cutting edges on their lateral and medial margins; first two teeth on each side of symphysis in both jaws noticeably longer than others; those in upper jaw closely followed by a very much smaller third tooth, and the latter by a distinct gap before larger lateral teeth begin; first two upper teeth slightly oblique to curved in outline; in side view these first two upper teeth are virtually straight except for their tips which curve outward; lateral teeth oblique in outline, and progressively smaller toward angles of jaws. In lower jaw the third tooth smaller than first two teeth but at least as large as fourth, and the gap between third and fourth teeth not greater than that between fourth and fifth; first lower tooth distinctly narrower than second; first two lower teeth weakly flexuous in outline; in side view the first two lower teeth are curved inward except for their tips which are reverse curved like those of upper teeth; lateral teeth oblique and diminishing in size toward angles of jaws. Two or three rows of teeth functional at center of mouth in both jaws, one or two rows along sides.

First dorsal fin fairly large, its height 1.1 to 1.2 times its base, and 1.2 in distance from posterior margin of eye to first gill opening; length of rear tip of first dorsal 3.7 to 3.6 in first dorsal height; apex of first dorsal moderately rounded, anterior margin weakly convex, distal margin more strongly convex along its upper two-thirds but concave below; origin of first dorsal varying from well behind to almost above posterior (inner) corner of pectoral fin; rear tip of first dorsal anterior to pelvic fin origin by a distance of about 1½ times length of pelvic base. Second dorsal fin very small, short based but with a rather long rear tip; height of second dorsal 1.2 to 1.0 times its base, and one-tenth to one-ninth of height of first dorsal; length

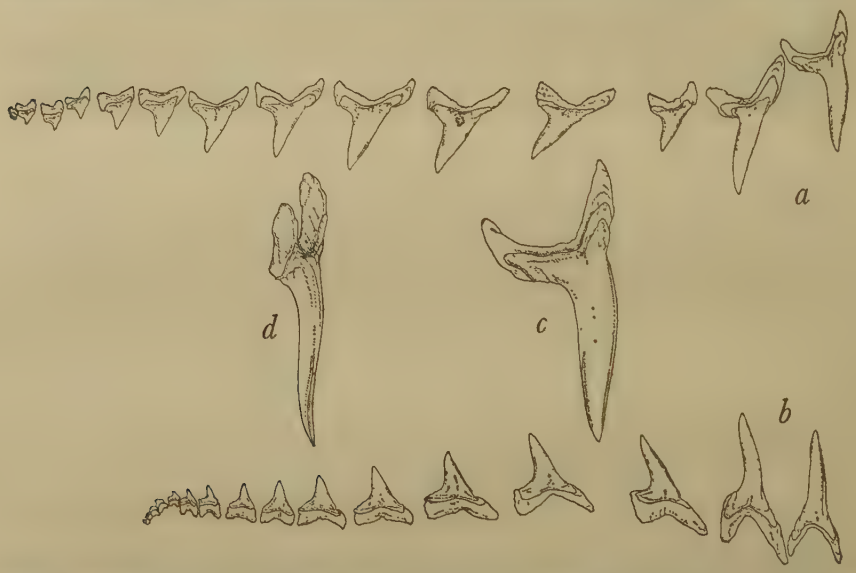

FIGURE 9.—*Isurus oxyrinchus*, Scripps Inst. Oceanogr., 54–140, Baja Calif.: *a*, *b*, upper and lower teeth, right side; *c*, *d*, first upper tooth, right side, anterior and lateral views, showing incomplete cutting edge on lateral margin. (The jaw from which these teeth were drawn is of comparable size to that of *I. alatus* in figure 8.)

of rear tip almost twice second dorsal height; origin of second dorsal well anterior to anal origin. Caudal fin somewhat lunate in outline, ventral lobe shorter than dorsal lobe, terminal lobe strongly developed; length of ventral lobe 1.5 to 1.4 in dorsal lobe; length of terminal lobe measured from tip of dorsal lobe to base of subterminal notch 4.2 to 4.4 in dorsal lobe. Anal fin similar in shape to second dorsal fin but slightly larger; origin of anal fin slightly behind or just below posterior end of second dorsal base. Pelvic fins moderately large, anterior margins equal to or a little longer than bases, and only slightly shorter than distal margins; length of pelvic base 1.7 to 1.9 in first dorsal base. Pectoral fins remarkably long, only slightly

tapered, anterior (outer) corners moderately rounded; length of anterior margin of pectoral slightly greater than head length measured from tip of snout to most anterior part of fifth gill opening; when adpressed to side of body with anterior pectoral margin horizontal, anterior (outer) pectoral corner reaches about 90 percent of distance from pectoral origin to pelvic origin.

Color.—Grayish black above, white below; underside of snout and around mouth at least partly dusky, more so in largest specimen; dorsal fins and both lobes of caudal fin dusky black; pectoral fin dusky black above except for a translucent to white area at posterior (inner) corner; underside of pectoral fin white but with a narrow dusky band along anterior margin, and a broader dusky-black edging to anterior (outer) corner and outer half of distal margin; pectoral fin in largest specimen, in addition, with some black mottlings underneath; pelvic fin dusky black on anterior half of upper surface, white posteriorly and below except in largest specimen in which underside is partly black mottled; anal fin in holotype white, with a dusky-black blotch anteriorly; anal fins in paratypes with more dusky-black coloration, only distal margins remaining more or less white.

Vertebrae.—Vertebral counts as in table 2. Centra very regular over entire length of vertebral column. Centrum diameter considerably greater than centrum length, even in longest monospondylous centra at posterior region of abdomen. Diplospondyly occurs above anterior third to middle of pelvic base.

$$\frac{\text{Length}}{\text{Diameter}} \text{ of penultimate monospondylous centrum} = 0.63 \text{ to } 0.67$$

$$\frac{\text{Length of penultimate monospondylous centrum}}{\text{Length of first diplospondylous centrum}} = 1.28 \text{ to } 1.30$$

Discussion.—The specific name of *I. alatus* is the Latin adjective *alatus*=winged, and is given in reference to the extremely long pectoral fins of this species.

In view of the wide distribution of the few known specimens of *I. alatus* (central Pacific to Indian Ocean), it is rather surprising that the species has not been recognized before. The chief reason for this may be that it is a truly oceanic species, not coming inshore as does *I. oxyrinchus*. If this is the case, it is understandable that it has not been taken during routine oceanographic explorations, few of which have been equipped to catch fishes as large as isurid sharks. The comparatively recent discovery of the abundance of other oceanic sharks such as *Carcharhinus falciformis* and *C. longimanus* in the western North Atlantic is a parallel situation. The larger eyes of *I. alatus* suggest the possibility that it lives in rather deeper water than *I. oxyrinchus*.

Addendum

Accounts of the following two species have appeared since the present revision was prepared.

Isurus paucus Guitart Manday, 1966, was proposed as a new name for *Lamna punctata* of De Kay (1842) but was based on 3 adult specimens (female 2,450 mm. t.l.; male 2,030 mm., and female 2,260 mm. long from snout tip to precaudal pit) from Cuba. The measurements, description, and discussion of the Cuban specimens in Guitart Manday's account leave no doubt that his *paucus* is conspecific with my *alatus* described here on p. 677. In consequence, *alatus* becomes a junior synonym of *paucus*. Guitart Manday's proposal, however, that *paucus* is the same species as De Kay's *punctata* is open to question although whatever the answer, it will not affect nomenclature.

Lamiostoma belyaevi Glückman, 1964, was described on dental characteristics from material taken in deep water in the Pacific. Glückman (1964, p. 105) designated *belyaevi* as type species of a new genus *Lamiostoma*, which he placed in a new family, Lamiostomatidae. He diagnosed the Lamiostomatidae as having more than 3 and up to 8 functional teeth in the first series on each side of the symphysis of the jaw, whereas in his family Isuridae there are only 1 to 3 functional teeth. Glückman's illustrations of *belyaevi* (fig. 31, a photograph of the anterolateral aspect of a dried, mounted specimen; fig. 32, a photograph of the lower jaw, possibly of the same specimen as in fig. 31; and pl. 31, figs. 13, 14, 18, and 19, photographs of individual teeth) strongly suggest that he had an *Isurus* and that the high number of apparently functional teeth was due to exposure of the replacement teeth behind those normally functional (this could well be due to removal of the inner labial membrane surrounding the replacement teeth when the specimen was prepared for mounting). Figure 31 also suggests that *belyaevi* has notably long pectoral fins and is dark colored or dusky under the snout and head—features characteristic of *I. paucus*. Evaluation of the status of *belyaevi*, however, cannot proceed until more information is available, particularly on its proportional dimensions, its teeth, and its color.

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TABLE 1.—*Some proportional dimensions of short-finned* Isurus

	A First dors. base as % t.l.	B Snout to pect. orig. as % t.l.	C Snout to first dors. orig. as % t.l.	D Pect. orig. to first dors. orig. as % t.l.	E Pect. axil to pelv. orig. as % t.l.	F Snout to pect. orig. / Pect. orig. to first dors. orig.	G Snout to pect. orig. / Pect. axil to pelv. orig.	H Pect. orig. to first dors. orig. / Post. of eye to first gill	I Post. of eye to third gill / First dors. height	J Dorsal lobe caudal / Ventral lobe caudal
SPECIMENS STUDIED										
605 mm. to 1,400 mm. t.l.										
Range	8.4– 9.3	24.5–28.8	36.7–40.3	8.9–13.9	20.7–27.6	1.76–3.22	0.89–1.35	0.70–1.38	1.74–2.20	1.23–1.48
Mean	8.9	26.8	38.0	11.2	23.5	2.46	1.16	0.98	1.98	1.37
No. of specimens	10	10	10	10	9	10	10	10	9	8
1,401 mm. to 2,200 mm. t.l.										
Range	8.5– 9.9	25.3–27.1	34.7–38.4	9.4–12.7	22.9–24.8	2.04–2.83	1.03–1.17	0.79–1.27	1.50–1.83	1.19–1.40
Mean	9.0	26.1	36.9	10.8	24.1	2.45	1.09	0.99	1.68	1.29
No. of specimens	11	10	10	10	3	10	4	4	4	10
2,201 mm. to 3,200 mm. t.l.										
Range	7.7–10.3	24.0–28.0	34.8–40.5	8.3–13.0	24.1–34.5	1.85–3.29	0.77–1.10	0.85–1.30	1.30–1.67	1.20–1.41
Mean	9.0	26.4	37.6	11.0	27.5	2.41	0.94	1.04	1.51	1.30
No. of specimens	13	13	13	12	5	13	5	5	5	10
TYPES										
I. glaucus										
1,020 mm. t.l.	9.4	24.6	37.8	13.2	23.3	1.86	1.05	1.12	2.14	1.54
I. bideni										
1,195 mm. t.l.	8.8	26.3	38.0	11.7	22.2	2.24	1.18	0.99	–	1.28
I. gomphodon										
ca. 1,700 mm. t.l.	9.6	25.2	32.4	7.0	19.6	3.60	1.28	0.66	2.05	1.41
I. cepedii										
1,830 mm. t.l.	–	–	–	–	–	–	–	–	–	1.88
I. africanus										
2,540 mm. t.l.	10.0	25.1	40.2	15.3	29.6	1.64	0.84	0.82	1.48	1.21
I. tigris										
2,690 mm. t.l.	11.3	27.3	44.7	17.4	32.3	1.57	0.85	1.27	–	1.28
I. huidobrii										
2,900 mm. t.l.	8.3	28.9	37.5	8.6	23.8	3.36	1.22	–	–	–
I. dekayi										
3,100 mm. t.l.	11.5	–	35.2	–	–	–	–	–	–	1.19

TABLE 2.—*Proportional dimensions in percent of total length*

Item measured	[illegible] mm, [illegible] Japan, USNM 96705	9842 mm, Japan, MCZ 58071	9488 mm, New Zealand, Dept. M. 5004	9420 mm, South Africa, USNM 167586	9200 mm, W. of Azores, USNM 167706
Snout tip to					
[illegible] pseudobranch	4.8	4.1	3.8	4.7	3.9
eye	7.8	6.8	6.6	6.8	6.2
nostril	6.9	5.3	5.9	6.0	5.0
1st gill opening	22.5	19.7	18.4	19.8	19.6
3rd gill opening	23.7	24.4	23.4	23.8	23.4
5th gill opening	28.1	26.2	25.7	25.4	25.3
pectoral origin	28.1	26.2	25.7	25.4	25.3
pelvic origin	56.7	57.2	57.4	57.2	55.1
1st dorsal origin	37.4	38.0	38.7	36.7	34.7
2nd dorsal origin	70.2	71.6	72.3	71.8	69.2
anal fin origin	71.2	72.4	72.8	72.4	70.8
upper caudal origin	80.1	81.8	83.2	81.6	79.2
lower caudal origin	79.7	81.8	83.3	81.8	79.1
Nostrils					
distance between basal centers	4.0	3.7	3.5	3.4	3.4
Mouth					
width	7.1	7.0	7.7	6.5	6.5
length	7.1	6.5	6.5	6.5	5.8
Gill opening lengths					
1st	8.2	7.4	8.1	7.6	7.4
3rd	7.7	6.7	7.8	7.1	7.0
5th	7.9	7.1	7.5	7.3	7.5
Eye					
horizontal diameter	2.6	2.2	1.9	1.6	1.5
1st dorsal fin					
length of base	9.2	8.9	8.5	9.9	9.1
posterior margin	1.7	1.8	2.2	1.9	2.1
height	7.9	7.3	8.1	10.2	9.9
2nd dorsal fin					
length of base	1.1	1.2	1.1	1.2	1.0
posterior margin	2.1	2.2	2.2	2.2	2.2
height	1.4	1.2	1.1	1.3	1.2
Anal fin					
length of base	1.3	1.2	1.2	1.3	1.2
posterior margin	2.3	2.4	2.1	2.3	2.2
height	1.6	1.3	1.2	1.5	1.5
Pectoral fin					
length of base	6.9	6.7	6.7	7.2	6.9
anterior margin	18.4	17.0	16.4	17.4	17.6
distal margin	13.7	13.4	14.8	14.8	14.6
Pelvic fin					
length of base	5.8	4.7	5.3	5.9	5.6
anterior margin	5.0	4.5	3.8	4.5	4.3
distal margin	5.7	5.3	5.8	6.0	6.0
length of claspers	3.0	2.6	—	—	—

[illegible] tip of anal to pelvic

TABLE 2.—*Proportional dimensions in percent of total length*—Continued

Isurus oxyrinchus	♂705 mm. California UMMZ 94726	♂847 mm. Japan MCZ 35071	♀1438 mm. New Zealand Dom. M. 3014	♀1920 mm.[1] South Africa USNM 197686	♀2000 mm. W. of Azores USNM 197706
Caudal fin					
length dorsal lobe	21.8	19.6	20.5	20.6	20.8
length ventral lobe	15.7	14.9	16.0	16.1	17.6
Trunk at pectoral origin					
width	12.9	11.0	12.5	—	11.0
height	15.3	13.0	12.9	—	11.6
Dental formula	13–13 / 13–13	—	13–13 / 15–15	—	13–13 / 12–12
Total vertebrae	—	—	—	190	—
Precaudal vertebrae	—	—	—	111	—
Caudal vertebrae	—	—	—	79	—

Isurus alatus, new species	♂1233 mm. Indo-Pacific USNM 197427	♂1251 mm.[2] Central Pacific USNM 196024	♀1372 mm. Indo-Pacific USNM 197429	♂1801 mm.[2] Central Pacific USNM 196039	♂2150 mm.[2] Central Pacific
Snout tip to					
outer nostrils	4.3	5.4	4.4	5.1	5.0
eye	6.1	—	6.0	—	—
mouth	6.2	7.2	6.4	6.8	6.7
1st gill opening	19.7	—	19.7	—	—
3rd gill opening	23.1	—	23.6	—	—
5th gill opening	25.4	—	25.5	—	—
pectoral origin	25.4	25.6	25.5	23.5	24.9
pelvic origin	55.1	55.3	55.7	53.9	56.6
1st dorsal origin	36.5	38.2	37.2	36.9	38.6
2nd dorsal origin	69.4	70.3	68.9	70.2	71.3
anal fin origin	70.7	—	69.6	—	—
upper caudal origin	78.7	77.9	78.8	79.5	79.9
lower caudal origin	78.3	—	78.6	—	—
Nostrils					
distance between inner corners	4.5	4.6	4.3	4.3	4.1
Mouth					
width	7.9	7.9	7.4	7.9	6.8
length	6.4	5.4	6.2	6.0	6.1
Gill-opening lengths					
1st	7.9	7.1	6.7	7.6	6.5
3rd	7.4	7.5	6.6	7.2	6.3
5th	7.0	7.3	7.3	7.3	7.3
Eye					
horizontal diameter	2.2	2.0	2.1	2.1	1.9
1st dorsal fin					
length of base	8.6	8.8	8.0	8.2	8.7
posterior margin	2.6	—	2.8	—	—
height	9.6	9.4	9.9	9.7	10.0

See footnotes at end of table.

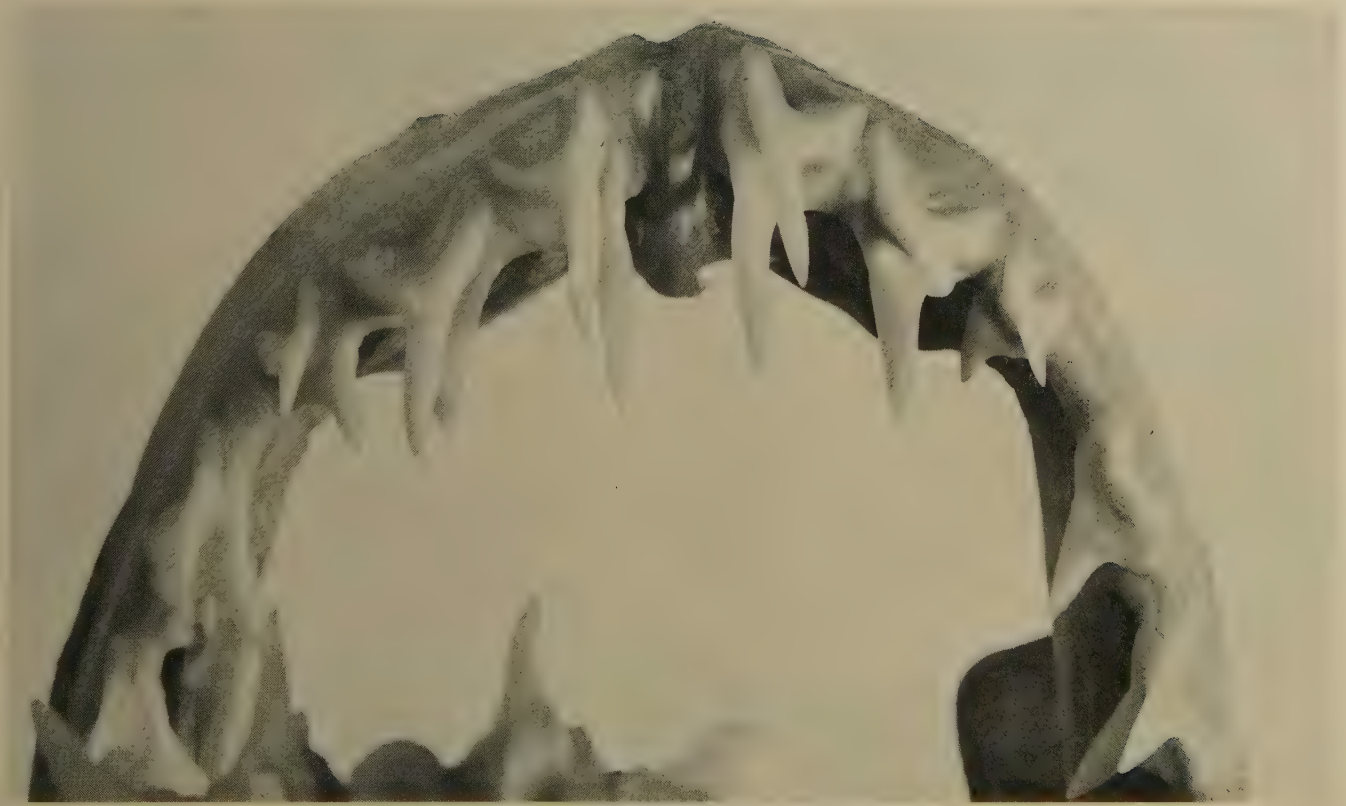
TABLE 2.—*Proportional dimensions in percent of total length*—Continued

Isurus alatus, new species	♂1233 mm. Indo-Pacific USNM 197427	♂1251 mm.[2] Central Pacific USNM 196024	♀1372 mm. Indo-Pacific USNM 197429	♂1801 mm.[2] Central Pacific USNM 196039	♂2150 mm.[2] Central Pacific
2nd dorsal fin					
length of base	1.0	1.0	0.9	0.8	0.8
posterior margin	1.9	—	1.7	—	—
height	1.1	1.1	1.0	0.9	0.9
Anal fin					
length of base	1.1	—	1.2	—	—
posterior margin	1.9	—	2.0	—	—
height	1.3	—	1.2	—	—
Pectoral fin					
length of base	6.3	—	6.0	—	—
anterior margin	26.4	25.1	26.5	24.4	25.0
distal margin	23.3	—	23.7	—	—
Pelvic fin					
length of base	4.9	—	5.1	—	—
anterior margin	5.4	—	5.2	—	—
distal margin	5.4	—	5.7	—	—
length of claspers	2.8	—	—	—	—
Caudal fin					
length dorsal lobe	22.0	22.1	22.0	20.5	20.1
length ventral lobe	15.0	15.9	15.5	16.8	15.2
Trunk at pectoral origin					
width	10.5	12.5	10.6	11.2	10.9
height	11.0	12.5	—	13.2	11.8
Dental formula	13–12 / 12–12	13–12 / 11–12	12–12 / 11–11	13–13 / 12–12	—
Total vertebrae	195	—	197	—	—
Precaudal vertebrae	112	—	111	—	—
Caudal vertebrae	83	—	86	—	—

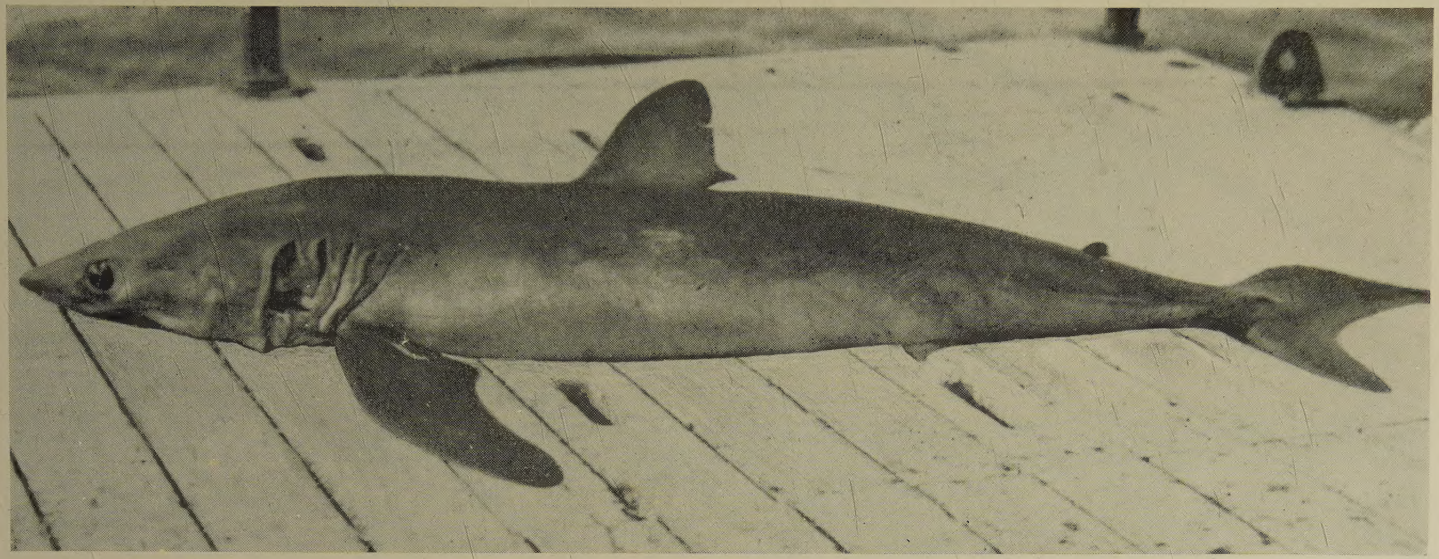
[1] Only the jaws of this specimen were preserved.

[2] Measurements supplied by Dr. Donald W. Strasburg. Only the jaws of these specimens were preserved.

Isurus alatus, new species, USNM 196039, male, 1801 mm., central Pacific, upper jaw. (U.S. Fish and Wildlife Service photo.)



Isurus oxyrinchus, Scripps Inst. Oceanogr. 54-140, Baja California, upper jaw of comparable size to that in plate 1. (U.S. Fish and Wildlife Service photo.)



Isurus alatus, new species, USNM 196024, male, 1251 mm., central Pacific. (U.S. Fish and Wildlife Service photo.)

Isurus alatus, new species, USNM 196039, male, 1801 mm., central Pacific: top, first dorsal fin; bottom, caudal peduncle from above. (U.S. Fish and Wildlife Service photo.)